

BOLTED CONNECTIONS

{ Shank $\rightarrow$ unthreaded portion }

Just tight $\rightarrow$ snug Tight

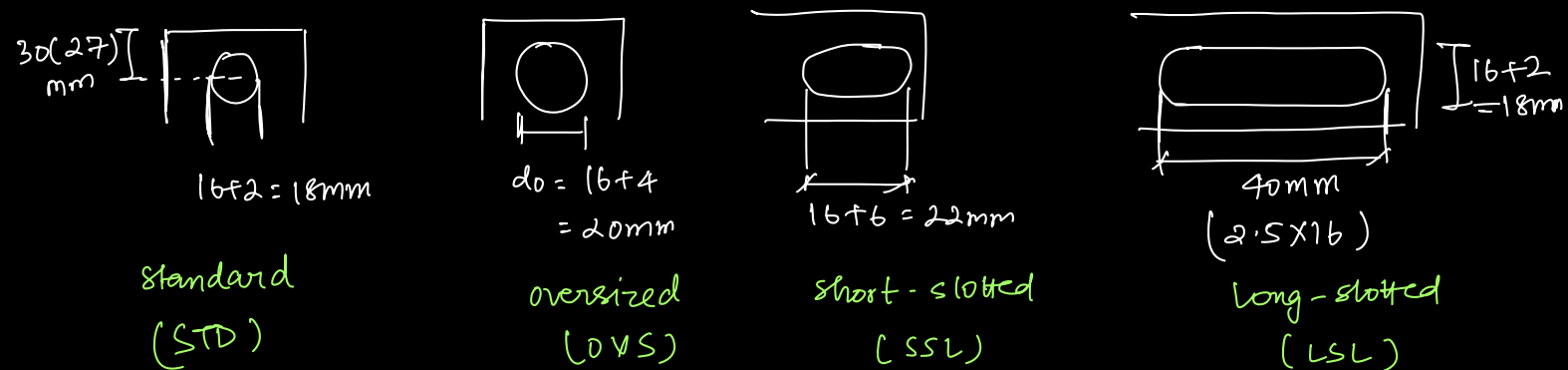
when extra tight $\rightarrow$ BOLT $\rightarrow$ Tension
PLATE $\rightarrow$ Compression.

Advantage

- The erection of the structure can be speeded up, and less skilled persons are required

Disadvantage

- Cost of material is high
- Normally there are loose fit
- Tensile strength of the bolt is reduced because of area reduction at the root of the thread and also due to stress concentrated.



Bolt size, d(mm)	12	16	20	22	24	27	30	36
Tensile stress area (mm ²)	84.3	157	245	303	353	459	561	817

at root of threads is 0.78 times nominal shank area of bolt.

$$0.78 \times \frac{\pi}{4} \times 16^2 = 157 \text{ mm}^2$$

$$A_{nb} = 0.78 A_{sb}$$

→ SHANK AREA.

MINIMUM EDGE DISTANCE OF BOLTS

clause 10.2.4.2

Distance in sheared and hand flame edge (mm)

$$\text{edge dist} = 1.7 \times \text{hole diameter}$$

Distance to rolled Machine flame cut, sawn edge

$$\text{edge dist} = 1.5 \times \text{hole diameter}$$

Grade 4.6

$$f_u = 4 \times 100 = 400 \text{ N/mm}^2$$

$$f_y = 0.6 \times 400 = 240 \text{ N/mm}^2$$

Grade 8.8

$$f_u = 8 \times 100 = 800 \text{ N/mm}^2$$

$$f_y = 0.8 \times 800 = 640 \text{ N/mm}^2$$

M 16 X 70
 ↓
 dia

↑ shank length
 (bolt length)

TYPES OF BOLTS

1. UNFINISHED BOLTS

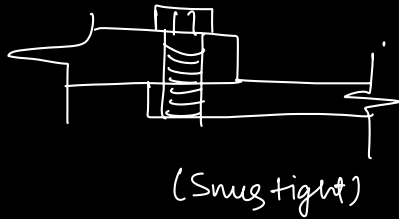
ordinary rough, common or black bolts

- It provides bearing type connections.
- light connections
- No friction is assumed

2. HIGH STRENGTH BOLTS (HSFG bolts):-

- It provides non-slip / slip critical / frictional type connection
- Medium and heavy structures
- Friction is developed b/w members since they are tightly clamped.

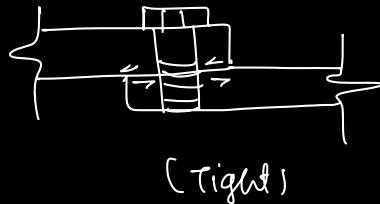
Ordinary bolts



- Failure takes place by shearing and bearing

- Slipping takes place

High strength friction bolts



- Non-slip connection (slipping will not take place)

- Failure by frictional slip

BEARING TYPE CONNECTION

STRENGTH OF BOLTED JOINT

load acting is larger than frictional resistance caused by

tightening of bolt.

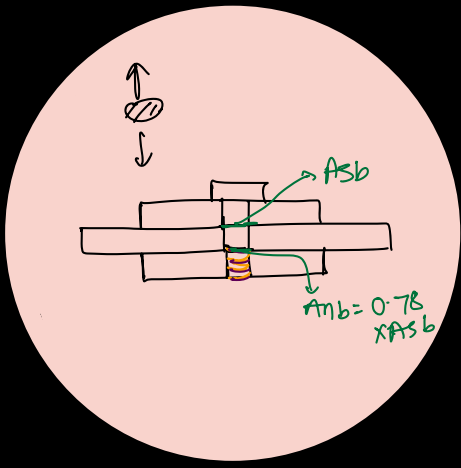
strength of bolt = min (Bolt value, Tearing str of plate)

Bolt value = min (Shearing str of bolt, Bearing str of bolt)

SHEAR STRENGTH OF BOLTS

nominal shear
capacity of bolt

$$V_{nsb} = \frac{f_u}{\sqrt{3}} (n_n A_{nb} + n_s A_{sb})$$



f_{ub} — ultimate tensile strength of bolt (N/mm^2)

n_n — no of planes intercepting threads

n_s = No of planes intercepting shank

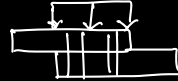
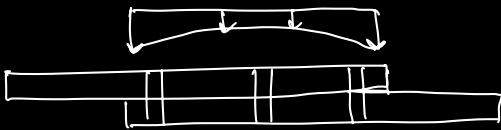
A_{nb} : root area of bolt (Threaded area)

A_{sb} : shank area of bolt

The nominal shear capacity of bolt for long joints, longer grips and with packing plates will be lesser.

$$V_{nsb} = \frac{f_u}{\sqrt{3}} \left[n_n A_{nb} + n_s A_{sb} \right] \cdot B_{ej} \cdot B_{lg} \cdot B_{pvg}$$

(i) Reduction factor for long joint



$$B_{ej} = 1.075 - \frac{l_j}{200d} \rightarrow \text{nominal dia}$$

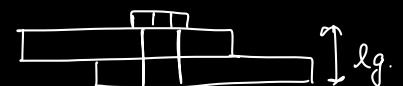
$$0.75 \leq B_{ej} \leq 1.0$$

$$\left\{ \begin{array}{l} l_j > 15d \end{array} \right\} \Rightarrow \text{long joint} \quad \left\{ \begin{array}{l} l_j = 15d \\ \text{then} \end{array} \right. \boxed{B_{ej} = 1.0}$$

(ii) Reduction due to large grip lengths (B_{lg})

$$B_{lg} = \frac{8d}{3d + l_g}$$

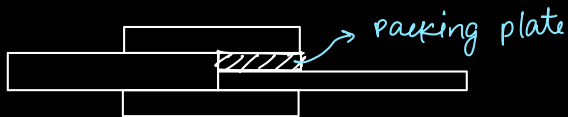
$$l_g > 5d \left\{ \text{LONG GRIP} \right\}$$



बढ़त पतली हो जाएगा
तो मज्जा जाएगा

$$B_{lg} \neq B_{ej} \quad \text{and} \quad l_g \neq 8d$$

iii) Reduction factor for packing plates (B_{pkg})



$$B_{pkg} = 1 - 0.0125 t_{pkg}$$

if $t_{pkg} > 6\text{mm}$

↓
thickness of thicker packing plate.

design shear capacity of bolt $\leftarrow V_{dsb} = \frac{V_{nsb}}{\gamma_{mb}}$
 $\rightarrow$ nominal shear capacity
 $\rightarrow$ Partial safety factor (1.25)

$$V_{dsb} = \frac{f_u}{\sqrt{3}} \times \frac{A_{nb}}{\gamma_{mb}} = \text{for single shear.}$$

$$V_{dsb} = \frac{f_u}{\sqrt{3}} \times \frac{A_{nb}}{\gamma_{mb}}$$

for single shear
SIMPLIFIED FORMULA



BEARING STRENGTH OF BOLTS

Nominal bearing capacity of bolt $\leftarrow V_{npb} = (2.5) \cdot K_b \cdot d \cdot t \cdot f_{up} \rightarrow$ ultimate capacity
 $\rightarrow$ thickness
 $\downarrow$
 Nominal dia

f_{ub} = ultimate of bolt
 f_{up} = ultimate of plate

$$\min \left\{ \begin{array}{l} \bullet \frac{e}{3d_o} = \frac{1.5d_o}{3d_o} = 0.5 \\ \bullet \frac{p}{3d_o} - 0.25 \\ \bullet \frac{f_{ub}}{f_{up}} = \frac{400}{410} = 0.975 \\ \bullet 1.0 \end{array} \right.$$

$d_o \rightarrow$ gross dia of bolt

$e \rightarrow$ end distance

$p \rightarrow$ pitch

design bearing capacity of bolt $\leftarrow V_{dpb} = \frac{V_{npb}}{\gamma_{mb}}$ $\rightarrow$ nominal bearing capacity of bolt

TENSILE STRENGTH OF BOLT

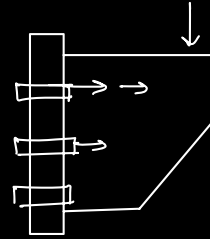
Nominal tensile capacity of bolt

$$T_{nb} = 0.9 f_{ub} A_{nb}$$

$\rightarrow$ accounts for safety at ultimate load

$\rightarrow$ net tensile area of bolt.

bolt (mm^2)



Desired tensile strength of bolt.

$$T_{db} = \frac{T_{nb}}{\gamma_{mb}}$$

Que

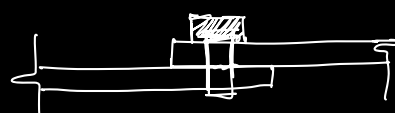
Calculate the strength of a 20mm diameter bolt of grade 4.6 for following cases. The main plates to be joined are 12mm thick

- Lap Joint
- Single cover butt joint, cover plate being 10mm thick
- Double cover butt joint, each cover plate 8mm thick

Solution

LAP JOINT

shear strength.



$$V_{dsb} = \frac{f_u}{\sqrt{3}} \times \frac{A_{nb}}{\gamma_{mb}} = \frac{400}{\sqrt{3}} \times \frac{245}{1.25} \times 10^{-3} = 45.26 \text{ kN}$$

Bearing strength,

$$V_{dpb} = \frac{2.5 K_b d t f_{up}}{\gamma_{mb}}$$

$$\text{hole dia } (d_o) = 20 + 2 = 22 \text{ mm}$$

$$\text{edge distance } (e) = 1.5 \times 22 = 33 \text{ mm}$$

$$\text{pitch} = 2.5 \times \phi = 2.5 \times 20 = 50 \text{ mm}$$

$$K_b = \min \left\{ \begin{array}{l} \bullet e/3d_o = \frac{33}{3 \times 22} = 0.5 \\ \bullet p/3d_o - 0.25 = \frac{50}{3 \times 22} - 0.25 = 0.5075 \\ \bullet f_{ub}/f_{up} = 0.975 \\ \bullet 1.0 \end{array} \right\} = 0.5$$

$$V_{dpb} = \frac{0.5 \times 2.5 \times 12 \times 20 \times 410}{1.25 \times 1000} = 98.4 \text{ kN}$$

$$\text{STRENGTH OF BOLT} = \min (V_{dsb}, V_{dpb}) = 45.26 \text{ kN} \quad \underline{\text{Ans}}$$

SINGLE COVER BUTT JOINT (10mm thick plate)

Shear strength

$$V_{dsb} = \frac{f_u}{\sqrt{3}} \times \frac{A_{nb}}{\gamma_m} = 45.26 \text{ kN}$$

Bearing strength

$$V_{dpb} = \frac{2.5 K_b d t f_{up}}{1.25} = \frac{2.5 \times 0.5 \times 10 \times 20 \times 410}{1.25 \times 1000} = 82 \text{ kN}$$

Thus

$$\text{STRENGTH} = \min (V_{dsb}, V_{dpb}) = 45.26 \text{ kN}$$

DOUBLE COVER BUTT JOINT (cover plate 8mm)

Shear strength

$$V_{dsb} = \frac{2 \times f_u}{\sqrt{3}} \times \frac{A_{nb}}{8m} = 2 \times 45.26 \text{ kN} = 90.52 \text{ kN}$$

Bearing strength

$$V_{apb} = \frac{2.5 K_b d t f_{up}}{r_{mb} \times 1000} = \frac{2.5 \times 0.5 \times 20 \times 12 \times 410}{1.25 \times 1000} = 98.4 \text{ kN}$$

$$\text{TWS STRENGTH} = \min (V_{dsb}, V_{apb}) \\ = 90.52 \text{ kN}$$

Ans

FR,

$$\text{strength of bolted joint} = \min \left\{ \begin{array}{l} \text{BOLT VALUE} \\ \text{AND} \\ \text{Tearing criteria of plate} \end{array} \right\}$$

SLIP CRITICAL CONNECTION

SHEAR STRENGTH OF HSFG BOLT

Slip critical / Non-slip / Friction type connection.

$$V_{nsf} = \mu_f \cdot n_e \cdot K_h \cdot F_o \quad \rightarrow \text{proof load}$$

↙
slip resistance

μ_f = slip factor

n_e = number of interface offering resistance

K_h = 1.0 (standard clearance holes)

0.85 (oversized and short slotted holes)

0.7 (long slotted holes)

$$F_o = A_{nb} \times \underbrace{0.7 \times f_{ub}}_{\text{proof stress}}$$

Proof stress = Max tensile stress

Maximum tensile force that bolt can carry without plastic failure

$\gamma_{mf} = 1.1$ for slip resistance designed at service load

$= 1.25$ for slip resistance designed at ultimate load.

If the force exceeds friction then the bolt will behave like bearing and shearing.

BEARING STRENGTH OF HSFG BOLT

$$V_{apf} = \frac{2.5 K_b d t f_{up}}{\gamma_{mf}}$$

TENSILE STRENGTH OF HSFG BOLT

$$T_d f = \frac{0.9 f_{ub} A_{nb}}{\gamma_{mf}}$$

• When service loads are applied, the connection do not slip and is k/a slip critical / Non-slip connection.

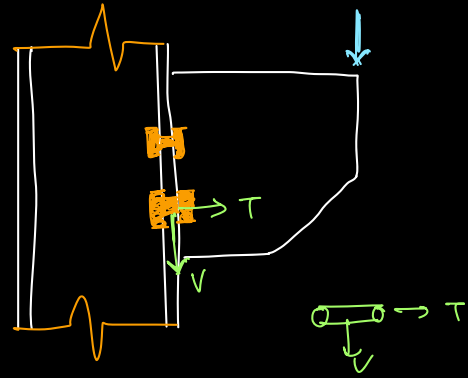
• But at ultimate loads connections generally slip and behave like bearing type connections.

§ TABLE 5 or 4 } Take a look

COMBINED SHEAR AND TENSION

The following equation is used to ensure safety of such connection:-

{INTERACTION EQUATION}



Bearing type connection

$$\left(\frac{V_{sb}}{V_{dsb}} \right)^2 + \left(\frac{T_b}{T_{db}} \right)^2 \leq 1.0$$

Friction type connection

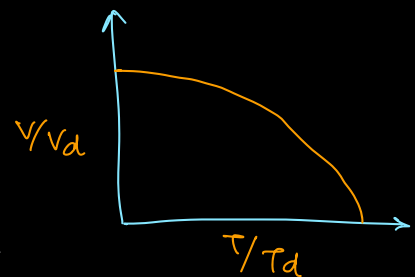
$$\left(\frac{V_{sf}}{V_{dsf}} \right)^2 + \left(\frac{T_f}{T_{df}} \right)^2 \leq 1.0$$

$V_{sb}/V_{sf} \rightarrow$ Factored shear force on bolt

$T_b/T_f \rightarrow$ Factored tensile force on bolt

$V_{dsb}/V_{dsf} \rightarrow$ Design shear capacity of bolt

$T_{db}/T_{df} \rightarrow$ Design tensile strength of bolt



Question

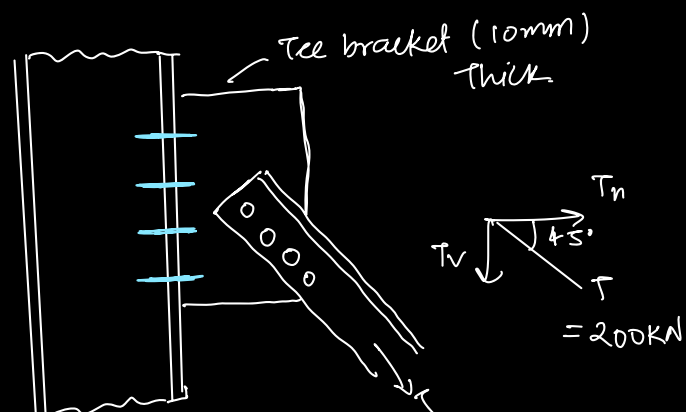
Determine whether the joint shown is safe or not. 8 bolts of 16mm diameter of grade 4.6 have been used for making the connection?

Solution

Total number of bolts = 8

Applied force = 200kN

Hor. component $T_H = 200 \cos 45$
 $= 141.42 \text{ kN} = T_V$
 $= \text{vertical comp.}$



$$\text{Tension in each bolt} = \frac{T_H}{8} = 17.68 \text{ kN}$$

$$\text{Shear in each bolt} = \frac{T_V}{8} = 17.68 \text{ kN}$$

$$16 \text{ mm dia bolt}; \quad d = 16 \text{ mm}; \quad \{d_o = 18 \text{ mm}\}; \quad A_{nb} = 157 \text{ mm}^2$$

$$\text{Assume } e = 1.5 \times 18 = 27 \text{ mm (Take 40)}$$

$$\text{pitch} = 2.5 \times 18 = 40 \text{ mm (Take 50 mm)}$$

$$f_{ub} = 400 \text{ N/mm}^2, \quad f_{up} = 410 \text{ N/mm}^2$$

SINGLE ANGLE

SHEAR CAPACITY

$$V_{dsb} = \frac{f_{ub}}{\sqrt{3}} \cdot \frac{A_{nb}}{\gamma_{mb}} = \frac{400}{\sqrt{3}} \times \frac{157}{1.25} \times 10^{-3} = 29.00 \text{ kN}$$

TENSILE STRENGTH

$$T_{db} = \frac{0.9 A_{nb} f_{ub}}{\gamma_{mb}} = \frac{0.9 \times 157 \times 400}{1.25} \times 10^{-3} \\ = 45.21 \text{ kN}$$

CHECK

$$\left(\frac{V_{sb}}{V_{dsb}} \right)^2 + \left(\frac{T_b}{T_{db}} \right)^2 \leq 1.0$$

$$\left(\frac{17.68}{29} \right)^2 + \left(\frac{17.68}{45.21} \right)^2 \leq 1.0$$

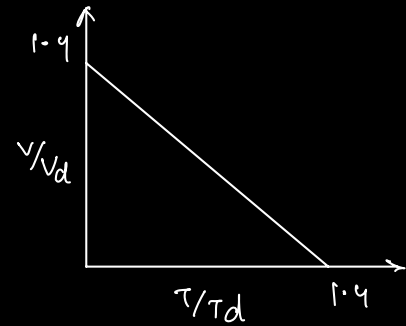
$$\{0.52 \leq 1.0\} \quad \text{THUS SAFE}$$

According to old code

$$\left(\frac{V}{V_d}\right) + \left(\frac{T}{T_d}\right) \leq 1.4$$

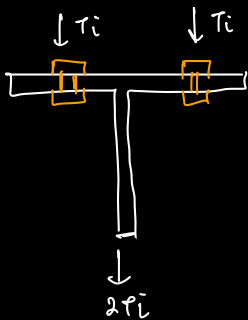
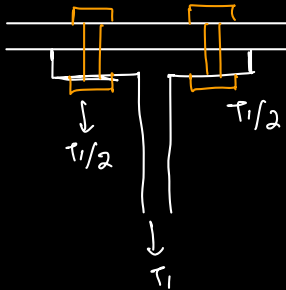
Interaction equation

- $\frac{V}{V_d} \leq 1.0$
- $\frac{T}{T_d} \leq 1.0$

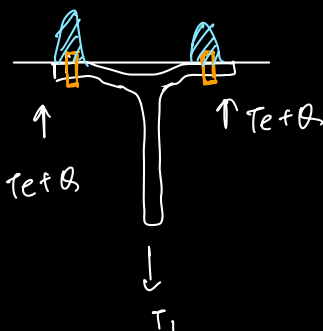


PRYING ACTION

SNUG TYPE BOLTS



PRE-TENSIONED LOADS

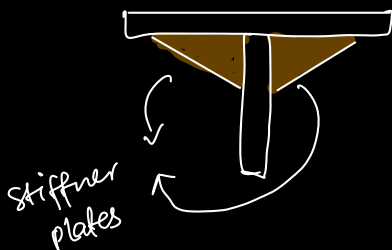


LOADS ON FLEXIBLE FLANGE

• When the flange bends the flange pushes the plate away and bolt experiences a tensile force.

$Q \rightarrow$ prying force

- Prying forces are generally developed in flexible T-hanger connections which reduces tensile load carrying capacity by exerting extra tensile forces (Q)



$\left\{ \begin{array}{l} \text{Flexible} \rightarrow Q \text{ will be present} \\ \text{Rigid} \rightarrow Q \text{ will be absent} \end{array} \right\}$